Investigating Household Vehicle Ownership, Mode Choice and Trip Sharing Decisions Using a Combined Revealed Preference/Stated Preference Nested Logit Model: Case study in Bangkok Metropolitan Region

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Abstract

This study proposes a Nested Logit model to investigate household travel behaviour in respect to vehicle ownership, mode choice and trip sharing decisions. The model is analysed using Revealed Preference (RP) and Stated Preference (SP) data since a combined estimation of RP/SP data is an effective method of expressing complex travel behaviour and forecasting travel demand for new transport services. In the proposed model, the nesting structure has two levels. The upper level shows car ownership, motorcycle ownership, and no vehicle-ownership choices, and the lower level shows the mode choice combinations for two-traveller households. Trip sharing is considered as one of the mode choice options in the model. The proposed model is analysed using data from the Bangkok Metropolitan Region. The analysis conducted informs that Central Business District (CBD) travel, long distance travel, household income, job status, age of travellers and presence of school children in households are key aspects in household travel decisions. Based on these aspects, households make important decisions on vehicle ownership, mode choice and trip sharing. In addition, this study reveals commuters’ hidden preferences for modes that are not in existence, in particular the Mass Rapid Transit System in the Bangkok Metropolitan Region due to be fully implemented in 2010.

Keywords

Travel behaviour, Developing countries, Nested Logit, Revealed preferences, Stated preferences
1. Introduction

Asian travellers show a great preference for private vehicles, notwithstanding the diverse transport options available in their transport systems (ADB, 2009). Vehicle ownership is often regarded as a status symbol (Goodwin, 1997). In addition to this symbolic value, private vehicles offer comfortable and safe travel opportunities to travellers. Inferior public transport services in Asian cities may also encourage travellers to use private vehicles for their travel.

Decision makers often emphasise the association between economic development and vehicle ownership growth (ADB, 2009). Southeast Asian countries have maintained a steady economic growth since early 1990s despite the deep recession over the two year period 1997-98 (Daquila, 2005). Figure 1 presents the vehicle ownership growth in the Asian cities Hong Kong, Jakarta, Bangkok, Seoul and Beijing for the ten years from 1993. Among these five Asian cities, Bangkok had the highest growth of vehicle ownership from 1993.

Figure 2 presents the modal share distribution in 2000 for the five Asian cities of Hong Kong, Jakarta, Bangkok, Seoul and Beijing. It reveals that the share of private vehicle use varies from 40% to 55% for all cities except Hong Kong. Hong Kong travellers seemed to use public transport alternatives due to diverse multi-modal public transport options available in the system (Annual Transport Digest, 2007).

In developing countries, the travel decisions of household members are known to be interrelated (Dissanayake, 2001; Zegras and Srinivasan, 2007). As a result, analysing individual travel behaviour may not be appropriate in investigating travel behaviour in such countries. Past research conducted in developing countries has been limited to analysing the travel behaviour of individuals. Recent research, however, emphasises the appropriateness of household travel behaviour in relation to transport policies in such countries (Dissanayake, 2008; Zegras and Srinivasan, 2007). This is equally valid for developed countries; Saleh and Farrell (2005) failed to reach conclusions about the suitability of transport policies in the UK as they did not attempt to incorporate household travel decisions into the models. Therefore, household travel behaviour is given attention in this research.

This study proposes a Nested Logit (NL) model to investigate household behaviour on vehicle ownership, mode choice and trip sharing decisions. The proposed NL model has two main levels. The upper level represents households’ car ownership,
motorcycle ownership and no vehicle-ownership choices, and the lower level stands for mode choices for two-traveller households. Trip sharing is considered as one of the mode-choice options in the proposed model.

Since combining revealed preference (RP) and stated preference (SP) data in travel behaviour models is a useful way in analysing complex travel behaviour and forecasting travel demand for new transport services, this research takes advantage of using both RP and SP data in the analysis. This research attempts to investigate the traveller preferences for the new Mass Rapid Transit System (MRT) in Bangkok Metropolitan Region (BMR) by developing a combined RP/SP NL model.

2. Incorporating Revealed and Stated Preference Data in Analysing Travellers’ Behaviour, and Attitudes to New Transit Systems

Estimation of discrete choice models generally relies on revealed preference data (RP data) when analysing travel behaviour on existing transport alternatives, systems and facilities. In contrast, stated preference data (SP data) collected from hypothetical travel scenarios is important when forecasting travel demand for new alternatives (Dissanayake, 2001; Zhang et al., 2008). Since actual travel data (RP data) cannot exist before the implementation of new modes, SP data plays a unique role in demand forecasting.

Although the use of SP data in travel behaviour modelling has several advantages over more conventional RP data, the reliability of the elicited preferences is somewhat uncertain (Dissanayake, 2001; Morikawa, 1989; Wardman, 1991). Wardman (1991) discussed the incorrect scale properties in SP choice models due to the influence of factors that do not affect actual travel behaviour and examined the consequences of the scale factor problem for demand forecasting. Since SP data collection is done using hypothetical scenarios, the SP data may generate partiality effects in the analysis (Morikawa, 1989; Zhang et al., 2008).

An early investigation of RP and SP combining techniques by Morikawa (1989) has been used extensively in travel behaviour modelling. The combined RP/SP model is used to rectify SP biases by introducing RP information into the model. Combined RP/SP estimations have been common in later travel behaviour research as they help improve the accuracy of parameter estimates while exploiting the advantages of both RP and SP (Ben-Akiva and Morikawa, 1990; Dissanayake and Morikawa, 2000; Morikawa, 1989; Polydoropoulou and Ben-Akiva, 2001).
Travel demand forecasting, especially for subway and MRT systems before their implementation, has been a key undertaking to investigate travellers attitudes to and likely behaviours on new systems (Dissanayake and Morikawa, 2000; Ben-Akiva and Morikawa, 1990; Hayashi et al., 1998; Polydoropoulou and Ben-Akiva, 2001). Polydoropoulou and Ben-Akiva (2001) investigated multiple mass transit technologies in the Tel-Aviv Metropolitan area using a combined RP/SP NL access/mode choice model. According to their estimation, the metro was the preferred mass transit alternative among the Mass Transit Technologies analysed in the model. Hayashi et al. (1998) conducted a SP data analysis to examine the suitability of an MRT system to reduce traffic congestion in Bangkok. According to the results, MRT is regarded as a positive contribution to the transport system in Bangkok and has the potential to gain 41% of the total transport share in the year 2010. 75% of demand diverted to MRT comes from previous bus users and the rest comes from car users. As proposed by Hayashi et al. (1998), improving access services to MRT stations would be beneficial to attract travellers to MRT.

3. Household Decisions on Travel in the Context of Asian Countries

3.1 What Decisions Dominate Household Travel Choices?

Researchers have identified that vehicle ownership is a fundamental element in the travel related decision-making process in Asian cities (Dissanayake, 2001; Tuan and Shimizu, 2005; Senbil et al., 2007; Hsu et al., 2007). When proposing a new transport mode in a vehicle-oriented society, transport user preference for private vehicle ownership has to be thoroughly investigated to reveal user preferences for a modal shift towards a new alternative (Dissanayake, 2001; Zhang et al., 2008). In Bangkok, economic development began in 1990s, and consequently vehicle ownership has been increasing in an uncontrolled manner (Figure 1). Therefore, vehicle ownership will be an important factor for household decisions regarding travel.

Figure 3 shows car ownership levels with respect to household incomes in Bangkok and the United Kingdom in 1995. The data for Figure 3 is taken from a major project in Bangkok (UTDM, 1998) and the National Travel Survey in the United Kingdom (NTS, 1995). Figure 3 clearly demonstrates that there is a lower chance that households in Bangkok will own multiple cars in comparison to households in the developed countries. As a result, it is a possibility that households in Bangkok share
trips among the household members. When a household makes a shared trip, they link different trip purposes by making intermediate stops (Dissanayake, 2001). Recently, household trip chaining and trip sharing have been of considerable research interest in Asian countries in general: in Thailand (Dissanayake, 2008) and China (Zegras and Srinivasan, 2007) in particular. Households in higher income category in developing countries even have a higher propensity for trip chaining or sharing (Zegras and Srinivasan, 2007).

The household travel survey in the BMR in 1995/96, showed that there was considerable motivation to generate shared car and motorcycle journeys to fulfil a number of travel requirements. Figure 4 shows the mode choice selection of two-traveller households in the BMR where one of the travellers in the household makes a work trip and the 2nd traveller of the same household makes a trip for any other purpose, for instance work, school, shopping, private business, social, or recreation. Accordingly, 13% households share cars and 16% of households share motorcycles to accomplish their travel needs such as work, shopping, personal business, social and recreation.

3.2. Methodology

Household decisions on vehicle ownership, mode choice, and trip sharing decisions are investigated in this research using an NL model. The conceptual framework designed for this research is presented in Figure 5. Since transport user preferences are considered as latent, this research exploits the advantage of using RP and SP data to reveal their hidden preferences.

Where possible household mode choice preferences, both RP and SP data, are incorporated in the analysis. However, analysing the preferences of vehicle ownership and trip sharing is conducted using only RP data as SP data for vehicle ownership and trip sharing are not available. SP data is used to analyse and forecast mode choices when a new mode appears in the system, for example, the MRT system in Bangkok as RP data does not exist. In addition to SP and RP data, the data related to household members are explicitly incorporated in the analysis.

This study investigates the travel decisions of households with two-travellers. According to the model requirement, one of the travellers in the household makes a work trip. The travel purpose of the second traveller in the household may be of any
type such as work, school, shopping, private business, social, or recreation. When they share a trip, the commuter has to travel to the destination of the second traveller before reaching the final destination (Figure 6). The commuter trip can be home-to-work (work-bound) or work-to-home (homebound). Therefore, detours on both work-bound and homebound are explicitly incorporated in the analysis. This is the main difference of this approach over conventional definitions, which deal with home-to-home trips as complete cycles. The commuting based shared trips accommodate a variety of household responsibilities since the commuter assists the second traveller of the household. Therefore, household shared trips serving trips in this study have to satisfy the requirements of both travellers who benefit from the trip chain with a minimum deviation from the commuter’s travel schedule. It is, therefore, necessary to consider travel attributes such as travel time, travel cost, distance between destinations, activity start and finish times and time of day when analysing the trip sharing decisions.

Since vehicle ownership, mode choice and trip sharing decisions are mutually interdependent, integrating them into the same modelling framework is important. Therefore, this study proposes a NL modelling approach as a suitable means to analyse multiple decisions.

4. Study Area and Data Description
The study area, the Bangkok Metropolitan Region (BMR) consists of the Bangkok Metropolitan Area (BMA) and five adjacent provinces: Samut Prakan, Nonthaburi, Pathum Thani, Nakorn Pathom and Samut Sakorn. There are 505 internal traffic zones in the BMR covering 7758 km$^2$. The population in the BMR was 13 million in the year 2001. Due to the severe traffic conditions in the BMR, the average travel speed has reduced to 10.9 km/h. The peak hour speed in the CBD was estimated as 5.9 km/h in the year 2001; this is relatively a lower peak hour speed compared to that in other Asian cities, for instance 10 km/h in both Kuala Lumpur (The Eighth Malaysia Plan, 2001) and Kolkata (Padam and Singh, 2004). Heavy traffic congestion means that commuters often have difficulty in accessing Bangkok.

In the mid-nineties, an MRT system was proposed to relieve the difficult situation in the BMR. The proposed MRT system was planned to provide wide coverage of the CBD and inner suburb areas in the BMR. The MRT system consists of six radial lines and an inner loop covering exclusively the central area of Bangkok (Figure 7).
According to the initial plan, the fully integrated MRT network of 175 km will be completed in the year 2010. In December 1999 one of the MRT lines (Sky Train or Green Line) was opened to the public. Initially, the usage of Sky Train was 150,000 passengers per day which was well below the original forecast of 400,000 passengers per day. After two years of operation, usage of Sky Train had increased to 300,000 passengers per day; during the two years a variety of promotions have been undertaken to attract travellers.

4.1. RP Data
The RP data that are used in this study were obtained from a household travel survey in the BMR during 1995/96. The survey was conducted as part of a major transport project in the BMR entitled the Urban Transport Database and Model Development Project (UTDM). The home interview survey collected household travel data for the BMR. According to UTDM (1998), the selection of households was based on a random sampling technique. The database consists of all attributes of the trips that were made on the date of the survey and information about the household members.

At the time of data collection, the available transportation modes in the BMR were bus, rail, car, motorcycle, hired motorcycle, taxi and ferry. Bus is the main transit facility in BMR. Rail transportation is not a popular mode in BMR as it gives access to a limited region. Ferry transportation in Bangkok also provides insufficient services and limited access. Since the usage of rail and ferry services was low, both rail and ferry are excluded from the analysis.

4.2. SP Data
The Infrastructure and Transportation Planning Laboratory at Nagoya University conducted an SP survey in 1996 to obtain information on user preference for the future MRT project in Bangkok. The SP questionnaire was prepared to collect information about commuter travel, and the data was collected from randomly selected individuals, either by face-to-face interviews or mailed questionnaires (Anurakamonkul, 1997). More specifically, the transport users were asked to select the preferred choice alternative from the hypothetical travel alternatives provided to them. The SP survey consists of three SP choices including MRT, bus and car.

In the SP questionnaire, attributes that relate to the SP choices were explicitly
incorporated; these were in the form of travel time, travel cost, travel speed, reliability, safety, comfort, service frequency, accessibility, intra modal transfers and access/egress time.

5. Modelling Household Travel Decisions Using a Combined RP/SP Nested Logit Model

The proposed model uses both RP and SP data in the analysis to improve the reliability of parameter estimates. Initially, the two models (the RP NL model and the SP MNL model) are estimated separately. Then, they are combined as the RP/SP NL model to investigate the combined effect. In the combined model, the segments of the SP model are analysed using SP data and the segments of the RP model are analysed using RP data while sharing the coefficients of the attributes that are common for both RP and SP databases.

5.1 Incorporating RP and SP Data Sources in Choice Models

In this research, RP data constitutes actual travel related choices, for instance, household members’ vehicle ownership, mode choice and trip sharing. The SP data captures mode choice behaviour of individuals over three main alternatives: MRT, bus, and car.

As proposed by Ben-Akiva and Morikawa (1990), the difference between the errors in RP and SP can be presented as a function of the variances of these errors $\varphi$ and $\xi$:

$$\sigma^2 = \mu^2 \sigma^2$$

where $\mu$ is an unknown scale coefficient.

SP data has more random noise than RP data, and therefore the scale coefficient ($\mu$) is usually less than unity (Morikawa, 1989).

According to Ben-Akiva and Lerman (1985), the utility ($U$) of an alternative can be represented using an observable component ($V$) and an unobservable component ($\varepsilon$). Adopting the formulations for the combined RP/SP model proposed by Ben-Akiva and Morikawa (1990), RP and SP utility functions ($U^{RP}$ and $U^{SP}$) can be written as follows:

$$U^{RP} = \beta'x^{RP} + \gamma' y^{RP} + \varphi^{RP}$$

$$\mu U^{SP} = \mu \left( \beta'x^{SP} + \lambda' x^{SP} + \xi^{SP} \right)$$
where,

\[ \mathbf{x} : \text{ vector of attributes that are commonly applied for the RP and SP choices} \]
\[ \mathbf{y} : \text{ vector of attributes that are related to the RP choices} \]
\[ \mathbf{z} : \text{ vector of attributes that are related to the SP choices} \]
\[ \beta', \gamma', \lambda' : \text{ vectors of unknown parameters} \]
\[ \varphi, \xi : \text{ unobservable components (error terms) of the RP and SP utilities} \]
\[ \mu : \text{ scale coefficient} \]

5.2. The RP Model

Since the RP database has a range of information related to household travel, the
analysis is conducted using an NL model that has two levels: the upper level is for
vehicle ownership choices and the lower level is for household mode choices regarding
their daily travel (Figure 8).

The two-level NL model proposed in this research uses the model specifications in
Bliemer et al. (2009). For the RP NL model, scale parameters for the upper and the
lower level are defined as \( \lambda_U \) and \( \lambda_L \), and among them \( \lambda_L \) is normalised to make the
estimation possible. By assuming index \( m \) represents an alternative at upper level
(branles representing the vehicle ownership choices, \( m=1\ldots M \)), and index \( j \) represents
an option at lower level (elemental alternatives representing household mode choices,
\( j \in J_m \)) of the nesting structure, the unconditional choice probability that a decision
maker, \( d \), chooses elemental lower level alternative \( j \) can be written as:

\[
P_{jd}^{RP} = \frac{\exp(V_{jd|m})}{\sum_{m=1}^{M} \sum_{j \in J_m} \exp(V_{jd|m})} \cdot \frac{\exp(V_{jd|m})}{\sum_{j \in J_m} \exp(V_{jd|m})}
\]

where, \( V \) represents the observed utility component.

According to the nesting structure proposed (see Figure 8), the upper level of the
model is characterised with three basic choices for vehicle ownership: Car ownership,
Motorcycle ownership, and No Vehicle ownership. The lower level represents the
corresponding mode choice combinations for two-traveller households. As stated earlier
in this paper, one of the travellers in the household makes a commuting trip while the
trip purpose of the second traveller in the same household may be of any type such as
work, school, shopping, private business, social, or recreation.

In the NL model, there are 17 mode choice combinations to represent household
travel patterns. In Figure 8, C, CSH, M, MSH, B, H, and T represent car, car sharing, motorcycle, motorcycle sharing, bus, hired motorcycle and taxi, respectively. Alternatives 1 to 7 in Figure 8 are the mode choice options for households with a car in which either the commuter uses a car (Alternatives 1~4) or both travellers travel by other modes (Alternatives 5~7). More specifically, Alternatives 1 to 4 are car using patterns in which the commuter (main traveller) travels by car and the second traveller of the same household selects one option from the available options of car sharing (CSH), bus (B), hired motorcycle (H), or taxi (T). In Alternatives 5 to 7, both travellers who belong to a car owning household but use B, H or T for their travel. Similarly, Alternatives 8 to 14 are the mode choices for the households who own motorcycles. Among them, Alternatives 8 to 11 are directly related to motorcycle use for commuter travel. For households who own neither car nor motorcycle, Alternatives 15 to 17 are the mode choice options in which both travellers use B, H, or T because they have to manage their travel needs by the other modes in the system. Other mode choice combinations for household travel such as B and H, B and T, and H and T are not included in the model due to data limitations. 1205 household trips are used to estimate the RP model.

5.3. The SP Model

This model is developed as a Multinomial Logit Model (MNL) to analyse anticipated individual travel behaviour. The model is estimated using 1240 hypothetical commuting trips made by individuals. The SP model analyses SP choice alternatives of MRT, bus and car. The attributes of travel time, travel cost, car ownership and first factor (the most important factor for the SP choice) are appropriately tested in the SP model.

5.4. The Combined RP/SP Nested Logit Model

When formulating the combined RP/SP NL model, the following points were taken into consideration:

- Coefficients of the level of service variables, both travel time and travel cost, are shared among all RP and SP utility functions in the lower level of the NL model.
- Mode specific constants for all modes are specified separately for the commuter and for the second traveller in the RP utility functions.
- Mode specific constants that are specified for commuters are made to share in the SP utility functions.

- A scale parameter ($\mu$) is included in the SP utility functions to observe the relative level of randomness in the RP and SP data sources.

- Scale parameters for the upper and the lower level are defined as $\lambda_U$ and $\lambda_L$, and among them $\lambda_L$ is normalised to make the estimation possible.

Some of the attributes of the lower level of the NL model are common to both RP data and SP data, for instance commuter mode choices; hence, equations (2) and (4) can be combined as equation (5). The logsum variables are appropriately included in the upper level of the NL model.

$$P_{jd}^{RP} = \frac{\left(\sum_{i=1}^{M} \exp(V_{id|m})\right)^{\lambda_U}}{\sum_{i=1}^{M} \exp(V_{id|m})} \cdot \frac{\exp(\beta'x^{RP}_{jd} + \gamma'z^{RP}_{jd})}{\sum_{i=1}^{M} \exp(\beta'x^{RP}_{id} + \gamma'z^{RP}_{id})}$$

(5)

For the SP model, the choice probability that a decision maker, $d$, chooses alternative $j$ can be written as:

$$P_{jd}^{SP} = \frac{\exp(\beta'x^{SP}_{jd} + \lambda^*z^{SP}_{jd})}{\sum_{i=1}^{M} \exp(\beta'x^{SP}_{id} + \lambda^*z^{SP}_{id})}$$

(6)

In equations (5) and (6), the vector of parameters $\beta'$ is common to both RP and SP datasets. A simultaneous estimation (full information maximum likelihood) method is used to estimate the combined RP/SP NL model.

The combined RP/SP NL model has several advantages over separate estimations of RP or SP data as follows:

- Results are more reliable as the analysis is based on the strengths of both RP and SP databases.

- Combined estimation exploits both types of data simultaneously in the analysis to help overcome the critical weaknesses of each of the databases, RP and SP.

- Combined estimation is useful to understand transport users’ preferences for the new modes.

- Model output can be used to forecast travel demand for the new modes.
6. Results and Discussion

The estimation results for the RP NL model (Model 1) and the combined RP/SP NL model (Model 2) are reported in Table 1. The model outputs provide useful information about travellers’ behaviours and attitudes to existing and future transport modes in the BMR.

In both models, mode specific constants were assigned in an individual basis for the commuter and the second traveller in the household aiming to investigate their individual preferences for travel modes. Since the SP dataset is confined to commuter based travel, it is more appropriate to have separate mode specific constants. Hence, the commuter related mode specific constants in Model 2 were jointly estimated using RP and SP data. The results obtained reveal that the car and the motorcycle are preferred modes for the commuters and the second travellers in Bangkok since the estimated parameters are positive and significant. The commuters show a great attraction for the future MRT system. The commuters do not like bus and hired motorcycle; the mode specific constants for these modes are negative in sign (Model 1: bus [-0.56], hired motorcycle [-1.16]; Model 2: bus [-0.55], hired motorcycle [-1.17]). In contrast, the second travellers show preference for the bus as well as the hired motorcycle alternatives.

The alternative specific constants based on the motorcycle ownership and no vehicle-ownership alternatives in the upper level of the nesting structure are positive and significant. Travel time and travel cost/income parameters are negative in sign and statistically significant. The negative sign indicates that increase in travel time or travel cost will decrease the utility.

As discussed earlier, the scale parameter for the bottom level of the nesting structure is normalised ($\lambda_1=1$) for both models. Accordingly, the estimated scale parameters for the upper level ($\lambda_U$) for Model 1 and 2 are 0.88 and 0.79 respectively. They are statistically significant and are within the specified range between 0 and 1, preserving the nesting specifications of the models.

In Model 2, the estimated scale coefficient ($\mu$) is lower than 1 and highly significant, confirming the premise that SP data contains more random noise than RP data. This corresponds to the findings of the previous research (Ortuzar and Willumsen, 2001; Zhang et al., 2008).

A variety of alternative specific dummies are included in Models 1 and 2 to
investigate household travel behaviour and attitudes in BMR. The male commuter
dummy in the car sharing (Alternative 1) and the motorcycle sharing (Alternative 8)
utility functions was positive in sign and statistically significant indicating male
commuters’ contribution to household travel responsibilities.

When the travel distances for both travellers in the household are more than 30 km,
the corresponding dummy variables in both models resulted in positive and statistically
significant values demonstrating household propensity for making separate trips, for
example car (commuter) and bus (second traveller). For longer trip distances, this also
indicates that the commuter drives alone by car, and the second traveller travels by bus
rather than making a shared trip. When the distance between the commuters’ and the
second travellers’ destinations is greater than or equal to 10 km, the corresponding
dummy variable is estimated with a positive significance indicating the household
preference for Alternative 9 (the commuter uses a motorcycle while the second traveller
uses bus). When the distance between destinations is less than or equal to 15 km, the
related dummy variable is positive and significant, highlighting the household tendency
towards car sharing (Alternative 1) or motorcycle sharing (Alternative 8). If the
second traveller’s travel distance is more than 5km, the car and hired motorcycle
(Alternative 3) is not a preferred household selection indicating that hired motorcycles
are not a suitable mode for distance travelling. When both travellers share the travel
for at least 75% of the total travel distance, motorcycle sharing is a likely option for
Bangkok travellers.

The commuters’ job is also analysed by introducing dummy variables for the
motorcycle sharing (Alternative 8), and the car ownership alternatives in the upper level
of the nesting structure. The commuters in the executive job category have a negative
preference for shared motorcycle trips. When the commuters’ job falls in the executive
or business categories, the corresponding dummy variable in the car ownership utility
function is significantly positive indicating their preference for car ownership.
Similarly, when the travellers’ jobs are not in the executive category, they do prefer not
to own vehicles. Commuters over fifty years of age prefer not to own vehicles.

Having school children has a positive influence on household car ownership. For
households with low incomes, no vehicle-ownership is an attractive option.

Travelling in the CBD is tested with several dummies. For the trips touching the
CBD, Alternative 2 (car and bus) is identified as an attractive mode selection for
households in the BMR. In other words, travelling through the CBD in the BMR is extremely difficult during peak congestion hours, and therefore, the commuter drives alone allowing the second traveller to use bus rather attempting to share trips in such an area. If household trips are in the CBD zone, Alternative 8 (motorcycle sharing), Alternative 16 (hired motorcycle and hired motorcycle), and the car ownership alternative are not preferred choices.

Commuters’ RP mode is tested in SP utility functions to investigate car and bus user attitudes to continuing with their prevailing modes. The corresponding dummies are positive and significant indicating the users’ hidden preference for continuing their RP mode. In other words, current car and bus users are more likely to continue using these modes for their commuting journeys in the future.

Car ownership is tested as a dummy in the MRT utility function and the related parameter is negative and significant indicating a preference for car use regardless of the new MRT system. This is consistent with the findings of Hayashi et al. (1998). First factor, in other words, the dominant factor for the mode choice is tested as a dummy in the MRT utility function. Travellers whose governing factors for their mode choice are either travel time or service reliability are likely to select MRT as their future mode since the estimated parameter is positive and statistically significantly.

Combined RP/SP Parameters (travel time, travel cost, and most of the dummy variables) in Model 2 have higher t-values than the corresponding RP parameters (Model 1) implying that they are more significant. This demonstrates the reliability of combined RP/SP model (Model 2) over RP model (Model 1). Further, Model 2 provides an opportunity to test a variety of variables (RP mode, vehicle ownership, first factor) in relation to the new MRT system.

The goodness of fit ($\rho^2$) of the models is found to be relatively high (0.39 and 0.35). The value of time (VOT) is calculated using the estimated coefficients of the travel time and the travel cost/income. The VOT values for the modes are 42 Thai Baht/hr (= GBP 1/hr) and 39 Thai Baht/hr (= GBP 0.9/hr) respectively. These values are comparable with the VOT values from other studies in the region (for example UTDM (1995) and ADB (2005)). The VOT for the RP model is slightly lower than the VOT for the combined RP/SP model. This finding is consistent with the findings from previous research by Bhat and Sardesai (2006) and Ortuzar and Willumsen (2001).
7. Concluding Remarks

This research investigates household travel behaviour in the BMR with explicit consideration of household decisions on vehicle ownership, mode choice and trip sharing. Two models, a RP NL model and a combined RP/SP NL model, are estimated intending to analyse household travel behaviour and attitudes to existing modes and to forecast commuter attitudes to a proposed MRT system in the BMR. The results of the research inform that combining RP and SP data in travel demand modes is an effective technique to investigate the complexities of travel behaviour and to forecast travel demand for future transport modes and services. It is also observed that the combined RP/SP NL model generates more reliable estimates when compared with the RP NL model.

The analysis explains that male commuters in the BMR have a positive influence on sharing trips indicating their contribution to household responsibilities. CBD travel, long distance travel, household income, job status, age of travellers and presence of school children in households emerged as the key considerations leading to household decisions on vehicle ownership, mode choice, and trip sharing. The results obtained from this research are realistic and can be effectively used for decision-making activities related to the transportation sector in developing countries in general and the BMR in particular. Further investigations of the proposed models will be focused on policy analysis.

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Figure 1   Vehicle Ownership Growth in Selected Asian Cities

Produced using the data from Doi (2005)
Figure 2  Modal Share Distribution in Selected Asian Cities

Produced using the data from Doi (2005), ICRA (2006), Susilo et al. (2007)
Figure 3 Car Ownership Levels with Respect to Household Income
(Bangkok City – 1995 and the United Kingdom – 1995)

Produced using the data from UTDM (1998) and National Travel Survey, UK (1995)
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Figure 7  Proposed Mass Rapid Transit Project in the Bangkok Metropolitan Region.
Source: MRTA Report, 1996
Figure 8 The RP NL Model to Investigate Household Travel Behaviour.
Table 1
Parameter Estimation Results: RP NL Model (Model 1) and Combined RP-SP NL Model (Model 2)

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<tr>
<th>Variable description</th>
<th>Model 1</th>
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<th>Coef.</th>
<th>t-stat.</th>
<th>Model 2</th>
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<td><strong>Mode specific constants (level 2 of the NL model)</strong></td>
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<tr>
<td>Commuter: Taxi (RP/SP) / 2nd traveller: Taxi (RP)</td>
<td>0.00</td>
<td></td>
<td>0.00</td>
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<td>0.00</td>
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<tr>
<td>Commuter/ 2nd traveller: Car (RP/SP)</td>
<td>1.52</td>
<td>5.22</td>
<td>1.43</td>
<td>4.88</td>
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<tr>
<td>Commuter/ 2nd traveller: Motorcycle (RP)</td>
<td>1.54</td>
<td>5.03</td>
<td>1.46</td>
<td>4.77</td>
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<tr>
<td>Commuter: Bus (RP/SP)</td>
<td>-0.56</td>
<td>-1.79</td>
<td>-0.55</td>
<td>-1.75</td>
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<tr>
<td>Commuter: Hired Motorcycle (RP)</td>
<td>-1.16</td>
<td>-3.15</td>
<td>-1.17</td>
<td>-3.15</td>
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<tr>
<td>Commuter: MRT (SP)</td>
<td>--</td>
<td>--</td>
<td>3.43</td>
<td>5.84</td>
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<tr>
<td>2nd traveller: Bus (RP)</td>
<td>3.17</td>
<td>11.21</td>
<td>3.01</td>
<td>10.49</td>
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<tr>
<td>2nd traveller: Hired Motorcycle (RP)</td>
<td>1.97</td>
<td>6.56</td>
<td>1.88</td>
<td>6.25</td>
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<td><strong>Alternative specific constants (level 1 of the NL model)</strong></td>
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<tr>
<td>Car-ownership : RP</td>
<td>0.00</td>
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<td>MC-ownership: RP</td>
<td>0.69</td>
<td>1.97</td>
<td>0.71</td>
<td>1.99</td>
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<td>No Vehicle-ownership : RP</td>
<td>2.23</td>
<td>5.38</td>
<td>2.10</td>
<td>4.83</td>
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<td><strong>Level-of-service variables</strong></td>
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<td>Travel time (hrs): RP/SP</td>
<td>-0.55</td>
<td>-4.48</td>
<td>-0.57</td>
<td>-4.63</td>
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<td>Travel cost/income/10^2: RP/SP</td>
<td>-2.15</td>
<td>-5.46</td>
<td>-2.51</td>
<td>-6.01</td>
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<td><strong>Scale parameters</strong></td>
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<td>$\lambda_{ui}$</td>
<td>0.88</td>
<td>5.87</td>
<td>0.83</td>
<td>5.92</td>
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<tr>
<td>$\mu$ (Scale parameter RP:SP)</td>
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<td>0.57</td>
<td>6.64</td>
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<td><strong>Alternative specific dummies</strong></td>
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<td>Male commuter, car and motorcycle sharing: RP</td>
<td>1.63</td>
<td>6.93</td>
<td>1.65</td>
<td>6.89</td>
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<td>Travel distance for both travellers &gt; 30km, car and bus: RP</td>
<td>1.61</td>
<td>3.16</td>
<td>1.80</td>
<td>3.40</td>
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<td>Distance between destinations ≥ 10km, motorcycle and bus: RP</td>
<td>1.01</td>
<td>5.44</td>
<td>1.06</td>
<td>5.49</td>
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<tr>
<td>Distance between destinations ≤ 15km, car and motorcycle sharing:</td>
<td>0.83</td>
<td>2.53</td>
<td>0.79</td>
<td>2.39</td>
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<td>Second travellers travel distance ≥5km, car and hired motorcycle:</td>
<td>-2.02</td>
<td>-2.75</td>
<td>-2.03</td>
<td>-2.76</td>
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<tr>
<td>Distance share of both travellers &gt; 75%, motorcycle sharing: RP</td>
<td>0.58</td>
<td>2.78</td>
<td>0.56</td>
<td>2.66</td>
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<tr>
<td>Commuter’s job (executive), motorcycle sharing: RP</td>
<td>-1.00</td>
<td>-4.03</td>
<td>-1.04</td>
<td>-4.15</td>
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<tr>
<td>Commuter’s job (executive or business), Car-ownership: RP</td>
<td>1.29</td>
<td>4.32</td>
<td>1.37</td>
<td>4.35</td>
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<tr>
<td>Travellers jobs are not executive, No vehicle-ownership: RP</td>
<td>0.51</td>
<td>2.63</td>
<td>0.54</td>
<td>2.64</td>
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<tr>
<td>Commuter’s age &gt;50 yrs, No vehicle-ownership: RP</td>
<td>0.59</td>
<td>1.99</td>
<td>0.63</td>
<td>2.00</td>
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<td>School children in the household ≥ 1, Car-ownership: RP</td>
<td>0.95</td>
<td>4.32</td>
<td>1.02</td>
<td>4.36</td>
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<tr>
<td>Household income ≤ 25000 Baht, No vehicle-ownership: RP</td>
<td>1.67</td>
<td>3.94</td>
<td>1.75</td>
<td>3.92</td>
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<tr>
<td>Trips touching CBD, car and bus: RP</td>
<td>0.82</td>
<td>4.43</td>
<td>0.87</td>
<td>4.62</td>
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<td>Trips within CBD, motorcycle sharing: RP</td>
<td>-1.01</td>
<td>-4.81</td>
<td>-1.04</td>
<td>-4.84</td>
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<tr>
<td>Trips within CBD, hired motorcycle and hired motorcycle: RP</td>
<td>-1.82</td>
<td>-3.39</td>
<td>-1.82</td>
<td>-3.40</td>
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<tr>
<td>Trips within CBD, Car-ownership: RP</td>
<td>-0.80</td>
<td>-3.56</td>
<td>-0.85</td>
<td>-3.57</td>
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<tr>
<td>RP mode, Bus, Car: SP</td>
<td>--</td>
<td>--</td>
<td>2.48</td>
<td>6.34</td>
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<tr>
<td>Car ownership or Car and Motorcycle ownership, MRT: SP</td>
<td>--</td>
<td>--</td>
<td>-0.89</td>
<td>-3.02</td>
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<tr>
<td>First factor: travel time and service reliability, MRT: SP</td>
<td>--</td>
<td>--</td>
<td>0.47</td>
<td>1.98</td>
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<tr>
<td><strong>Number of observations</strong></td>
<td>1205 (RP)</td>
<td>2445 (RP and SP)</td>
<td>L( $\hat{\beta}$ )</td>
<td>-1997.7</td>
<td>-2998.9</td>
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<td>L( 0 )</td>
<td>-3278.1</td>
<td>-4640.3</td>
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<td>$\rho^2$</td>
<td>0.39</td>
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<td>VOT (Thai Baht/hr)</td>
<td>42</td>
<td>39</td>
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Notes:
- Bold figures are significant at: *95%
- 0.00 in “Coef.” column indicates that the constant term set to zero.
- -- in Coef. and t-stat. indicates parameter not estimated and t-stat. not calculated respectively.